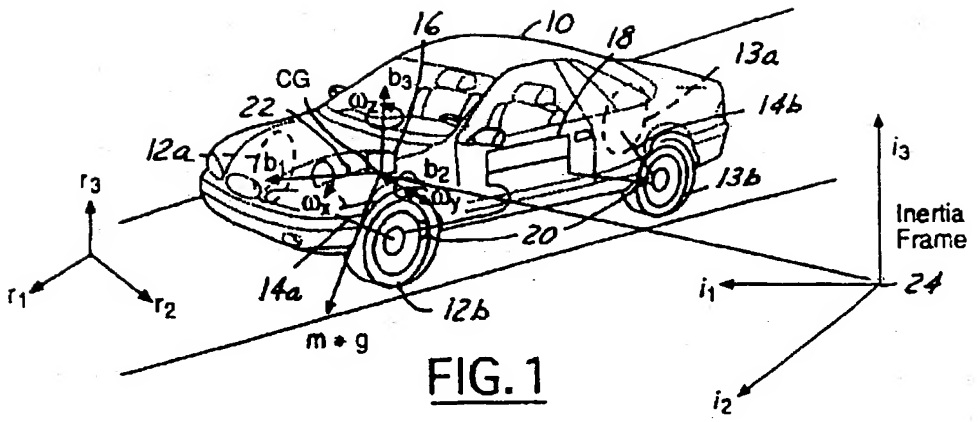
16
10
18
13a
CG
b3
22
14b
12a
b1
b2
13b
r3
i3
Inertia
Frame
20
r1
r2
14a
12b
i1
24
m * g
i2

FIG. 1

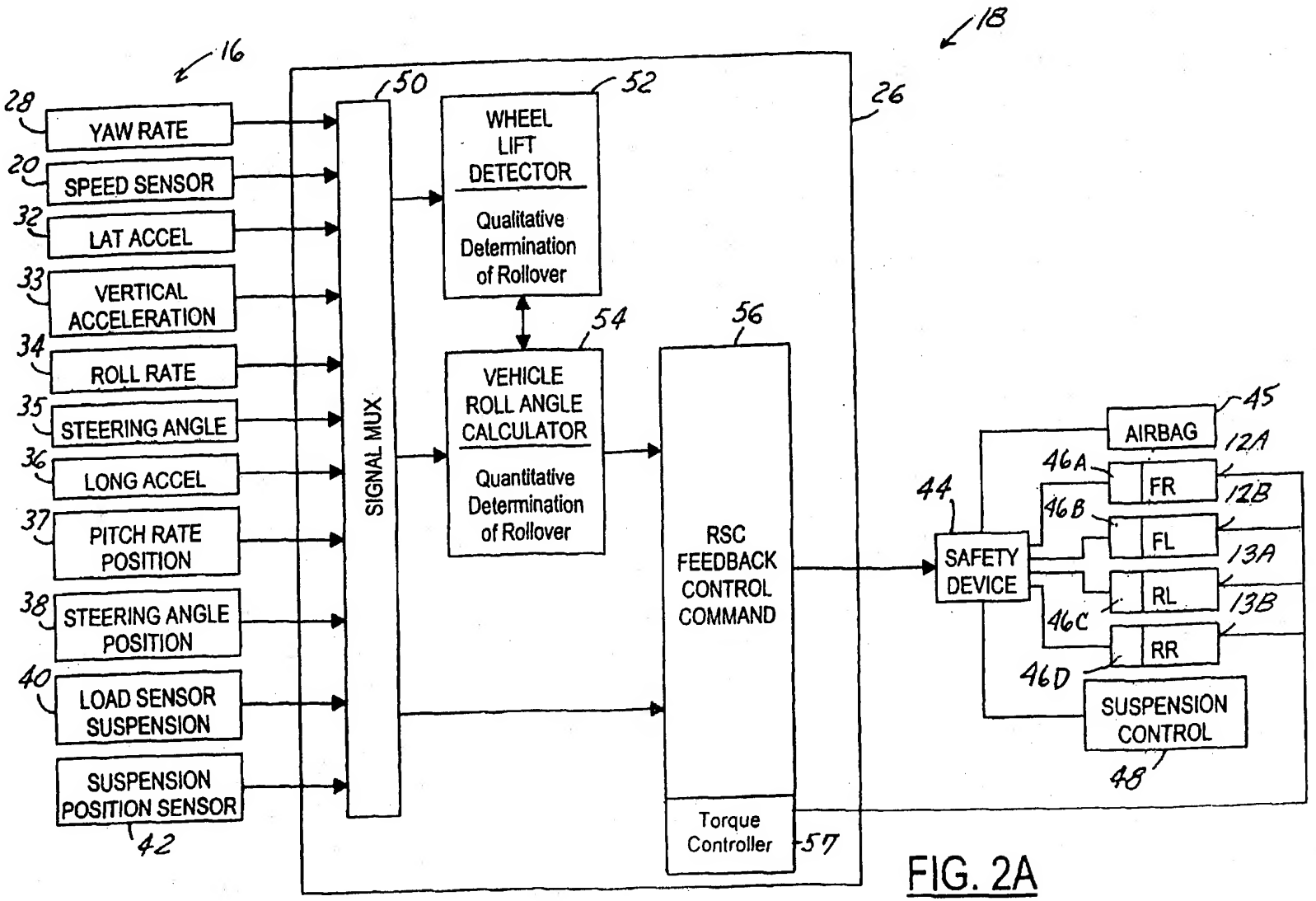
16
18
28
YAW RATE
20
SPEED SENSOR
32
LAT ACCEL
33
VERTICAL ACCELERATION
34
ROLL RATE
35
STEERING ANGLE
36
LONG ACCEL
37
PITCH RATE POSITION
38
STEERING ANGLE POSITION
40
LOAD SENSOR SUSPENSION
SUSPENSION POSITION SENSOR
42
50
SIGNAL MUX
52
WHEEL LIFT DETECTOR
Qualitative Determination of Rollover
54
VEHICLE ROLL ANGLE CALCULATOR
Quantitative Determination of Rollover
56
RSC FEEDBACK CONTROL COMMAND
Torque Controller
57
26
44
SAFETY DEVICE
45
AIRBAG
12A
46A
FR
12B
46B
FL
13A
RL
13B
46C
RR
46D
SUSPENSION CONTROL
48

FIG. 2A

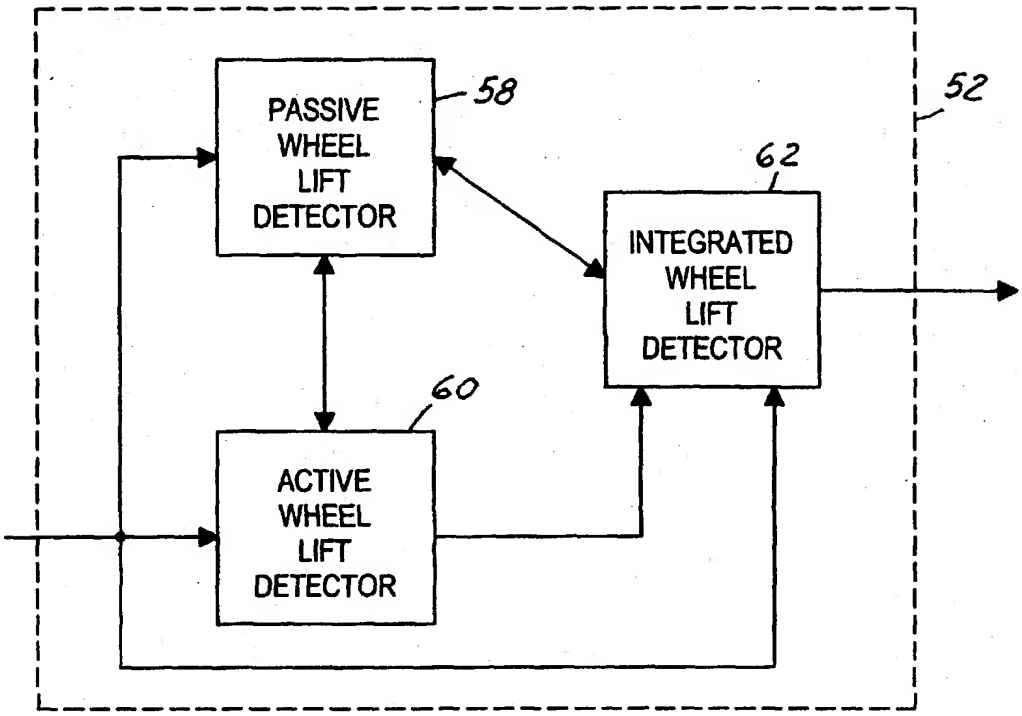
PASSIVE WHEEL LIFT DETECTOR
58
52
62
INTEGRATED WHEEL LIFT DETECTOR
60
ACTIVE WHEEL LIFT DETECTOR

FIG. 2B

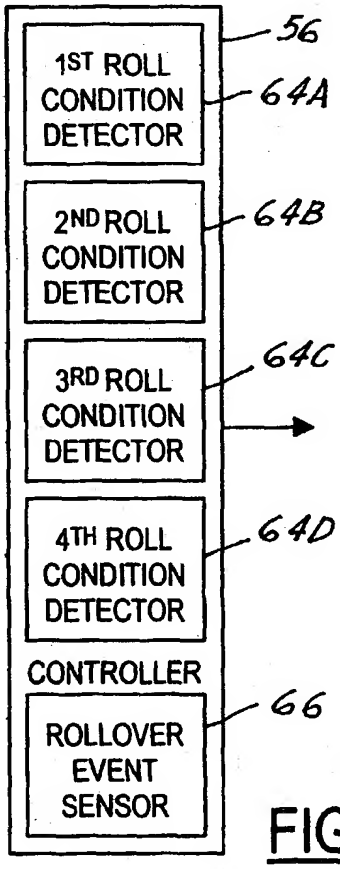
56
1ST ROLL CONDITION DETECTOR
64A
2ND ROLL CONDITION DETECTOR
64B
3RD ROLL CONDITION DETECTOR
64C
4TH ROLL CONDITION DETECTOR
64D
CONTROLLER
ROLLOVER EVENT SENSOR
66

FIG. 2C

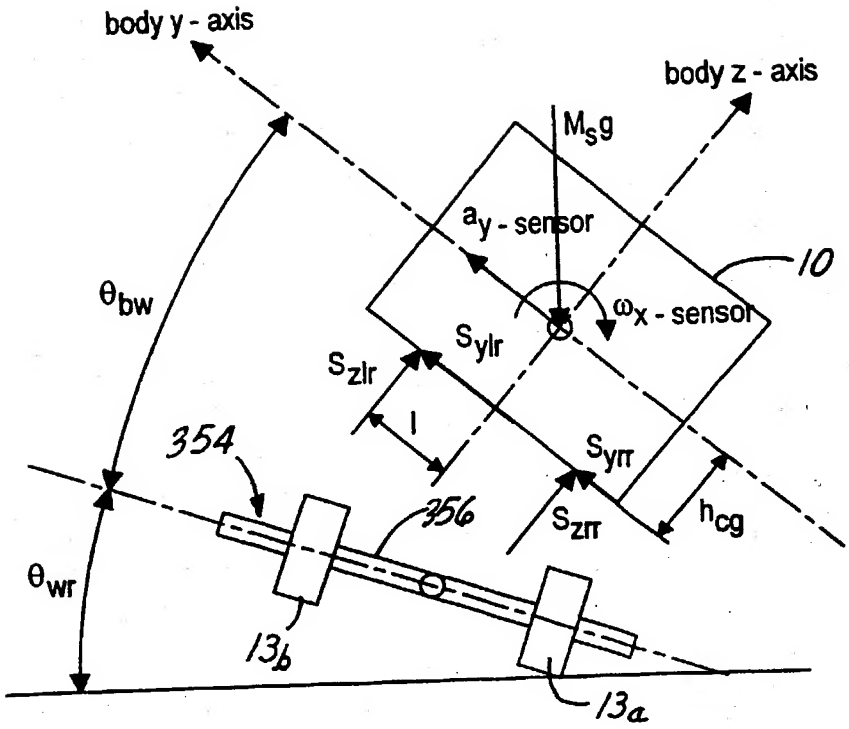
body y - axis
body z - axis
$M_S g$
a_y - sensor
ω_x - sensor
10
θ_{bw}
S_{ylr}
S_{zlr}
l
354
S_{yrr}
356
S_{zrr}
h_{cg}
θ_{wr}
13_b
13_a

FIG. 3

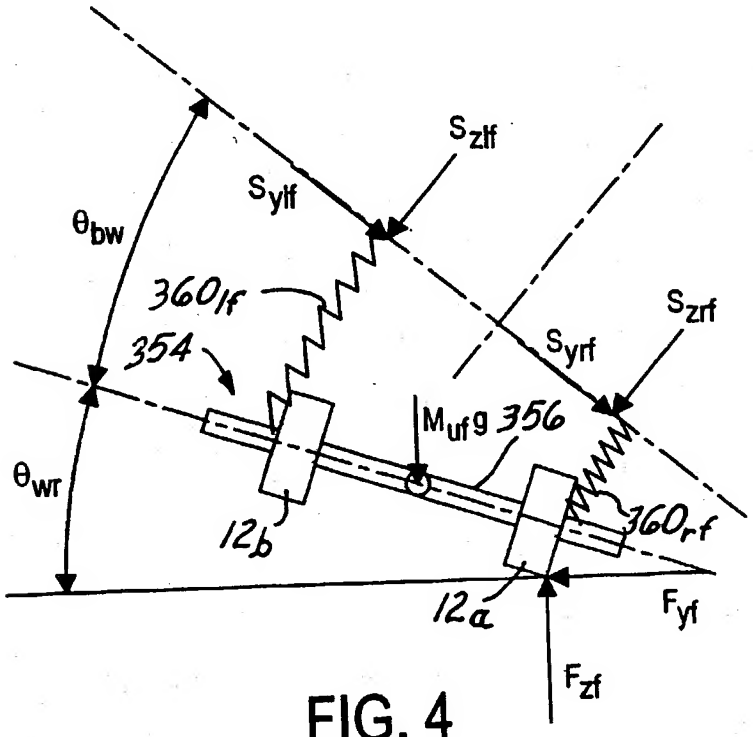
S_{zlf}
S_{ylf}
θ_{bw}
360_{lf}
354
S_{zrf}
S_{yrf}
$M_{uf} g$
356
θ_{wr}
360_{rf}
12_b
12_a
F_{yf}
F_{zf}

FIG. 4

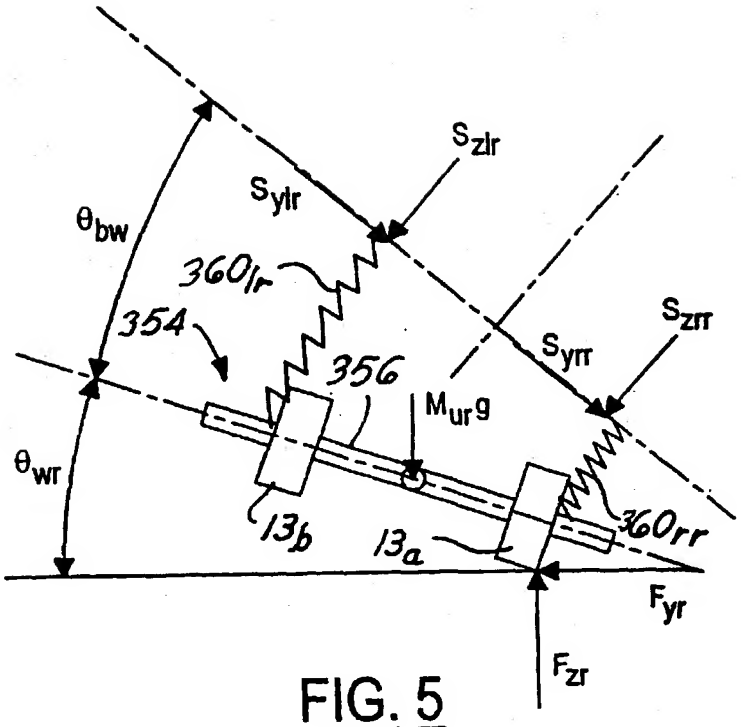
S_{zlr}
S_{ylr}
θ_{bw}
360lr
354
356
S_{zrr}
S_{yrr}
M_{urg}
θ_{wr}
13b
13a
360rr
F_{yr}
F_{zr}

FIG. 5

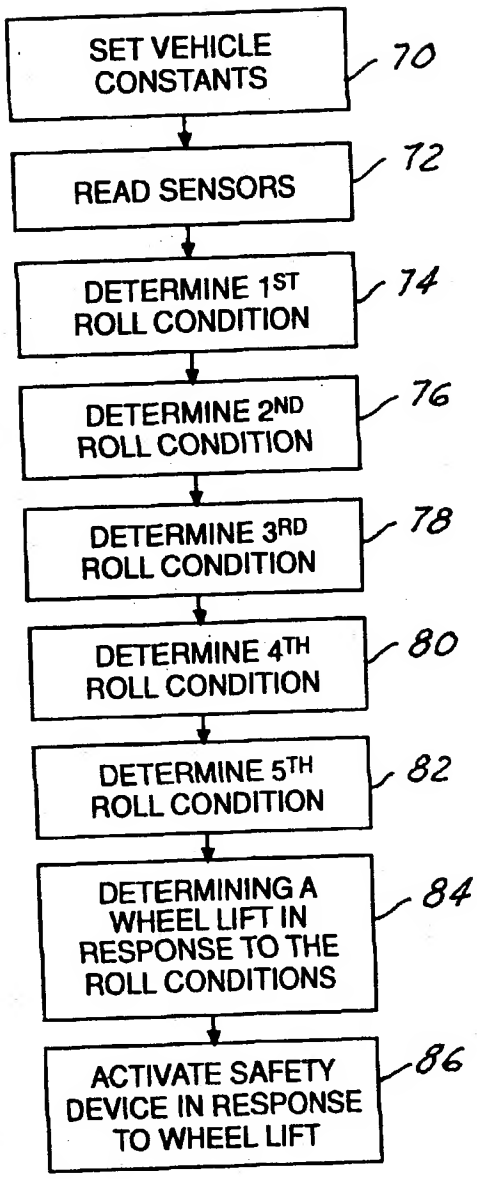
SET VEHICLE CONSTANTS
70
READ SENSORS
72
DETERMINE 1ST ROLL CONDITION
74
DETERMINE 2ND ROLL CONDITION
76
DETERMINE 3RD ROLL CONDITION
78
DETERMINE 4TH ROLL CONDITION
80
DETERMINE 5TH ROLL CONDITION
82
DETERMINING A WHEEL LIFT IN RESPONSE TO THE ROLL CONDITIONS
84
ACTIVATE SAFETY DEVICE IN RESPONSE TO WHEEL LIFT
86

FIG. 6

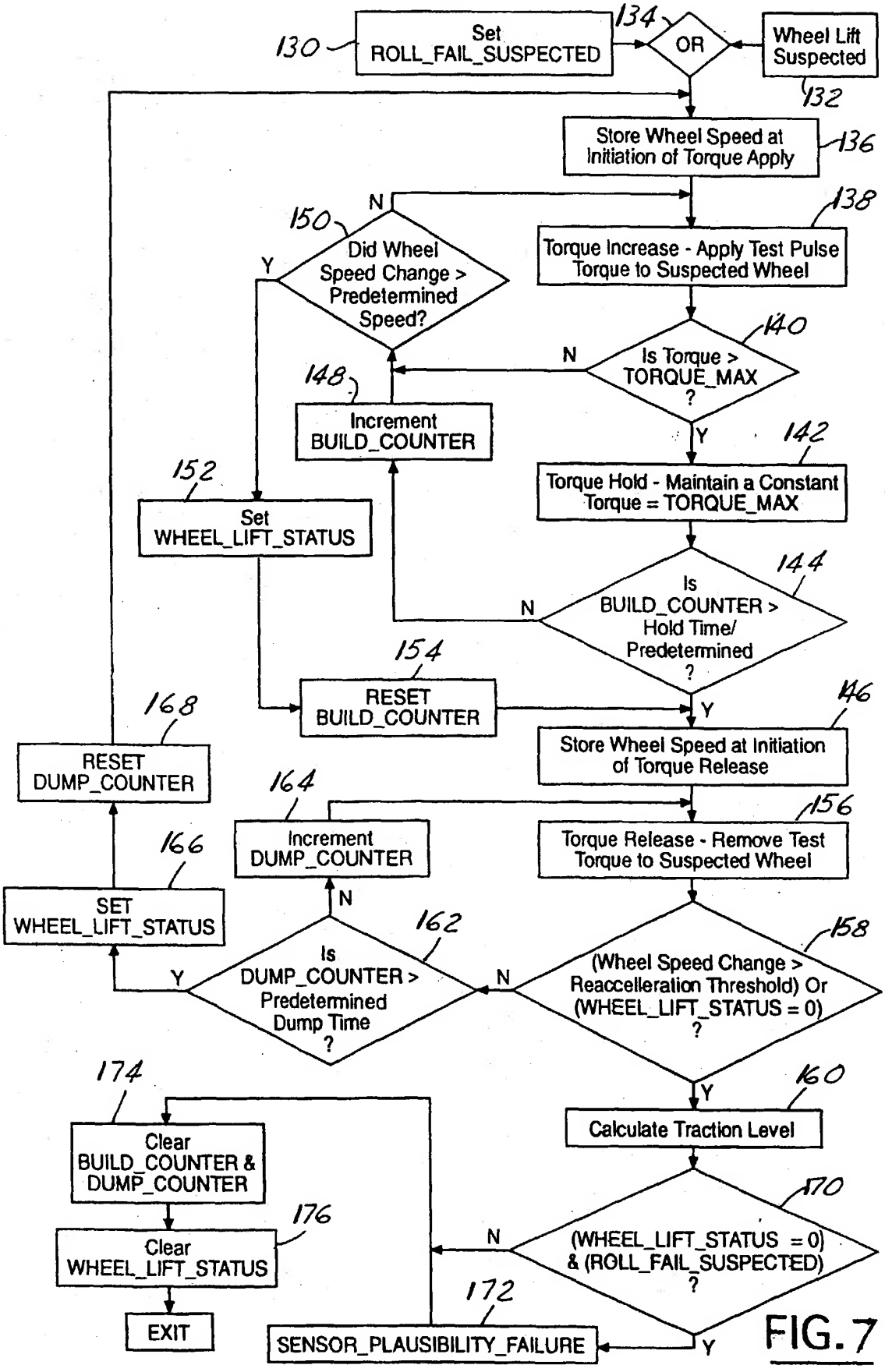
130
Set ROLL_FAIL_SUSPECTED
134
OR
Wheel Lift Suspected
132
Store Wheel Speed at Initiation of Torque Apply
136
138
Torque Increase - Apply Test Pulse Torque to Suspected Wheel
140
Is Torque > TORQUE_MAX ?
N
Y
142
Torque Hold - Maintain a Constant Torque = TORQUE_MAX
144
Is BUILD_COUNTER > Hold Time/ Predetermined ?
N
Y
146
Store Wheel Speed at Initiation of Torque Release
148
Increment BUILD_COUNTER
150
Did Wheel Speed Change > Predetermined Speed?
N
Y
152
Set WHEEL_LIFT_STATUS
154
RESET BUILD_COUNTER
156
Torque Release - Remove Test Torque to Suspected Wheel
158
(Wheel Speed Change > Reaccelleration Threshold) Or (WHEEL_LIFT_STATUS = 0) ?
N
Y
160
Calculate Traction Level
162
Is DUMP_COUNTER > Predetermined Dump Time ?
N
Y
164
Increment DUMP_COUNTER
166
SET WHEEL_LIFT_STATUS
168
RESET DUMP_COUNTER
170
(WHEEL_LIFT_STATUS = 0) & (ROLL_FAIL_SUSPECTED) ?
N
Y
172
SENSOR_PLAUSIBILITY_FAILURE
174
Clear BUILD_COUNTER & DUMP_COUNTER
176
Clear WHEEL_LIFT_STATUS
EXIT

FIG. 7

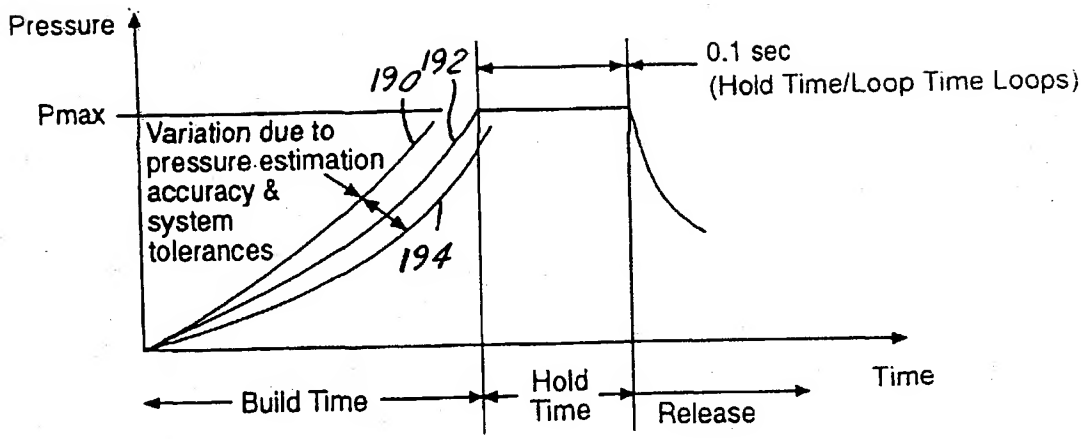
Pressure
Pmax
190
192
0.1 sec
(Hold Time/Loop Time Loops)
Variation due to pressure estimation accuracy & system tolerances
194
Time
Build Time
Hold Time
Release

FIG.8A

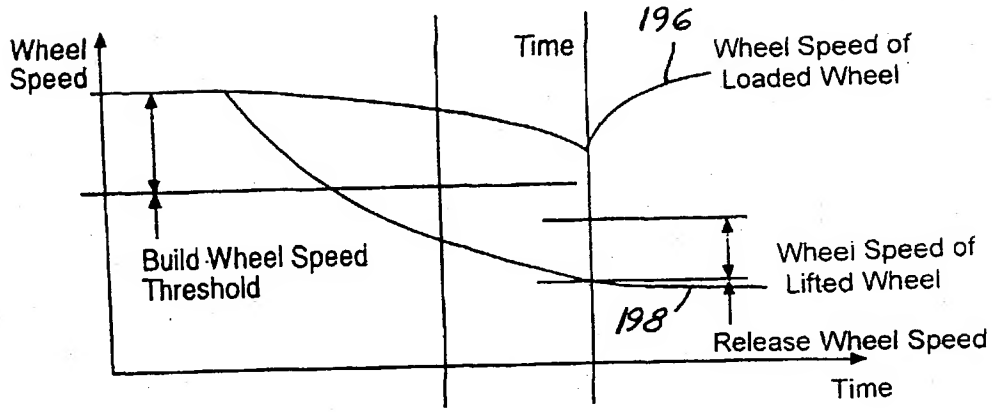
Wheel Speed
Time
196
Wheel Speed of Loaded Wheel
Build Wheel Speed Threshold
Wheel Speed of Lifted Wheel
198
Release Wheel Speed
Time

FIG.8B

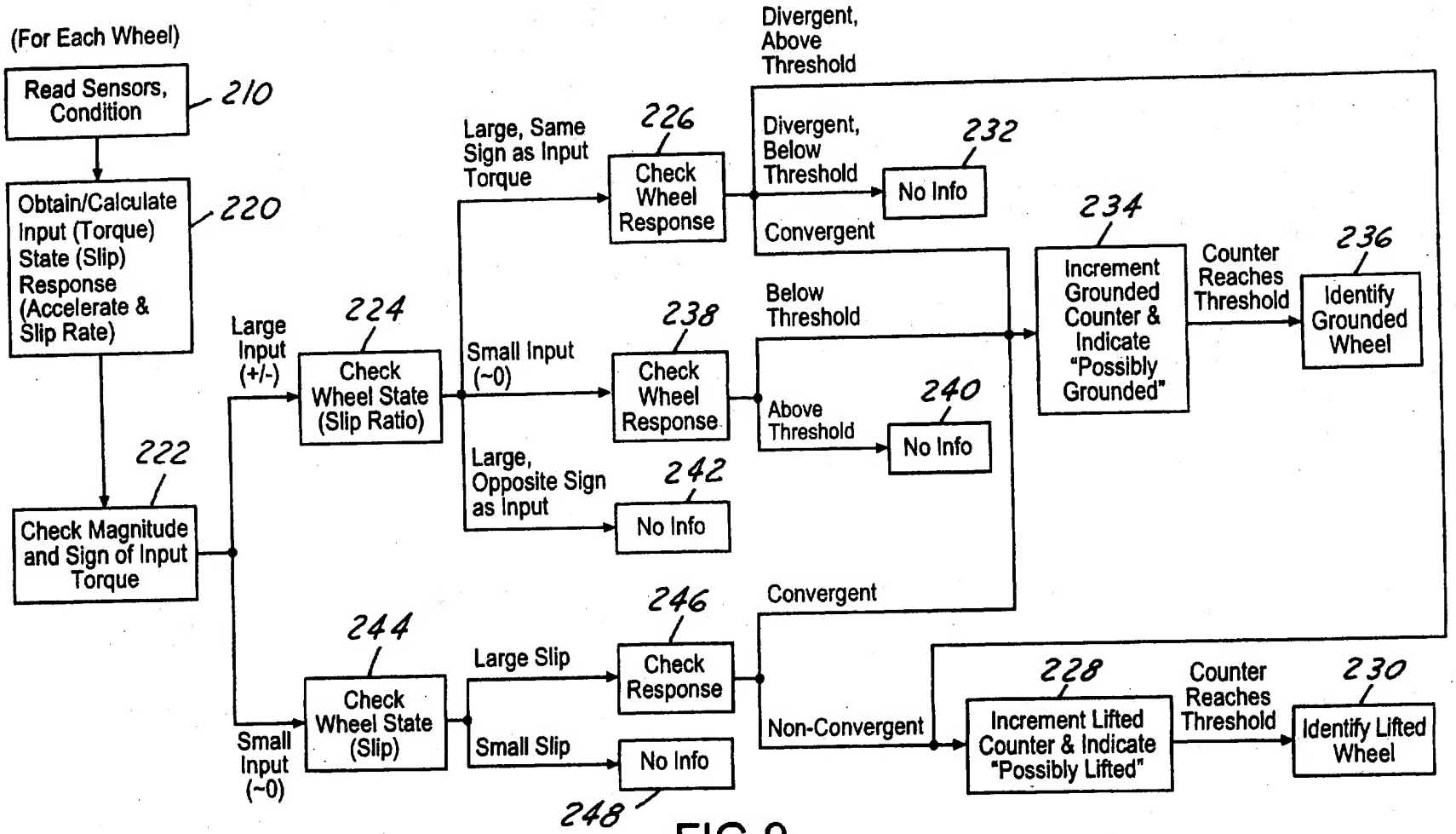
(For Each Wheel)
Read Sensors, Condition
210
Obtain/Calculate Input (Torque) State (Slip) Response (Accelerate & Slip Rate)
220
Check Magnitude and Sign of Input Torque
222
Large Input (+/-)
Check Wheel State (Slip Ratio)
224
Small Input (~0)
Large, Opposite Sign as Input
Large, Same Sign as Input Torque
Check Wheel Response
226
Divergent, Above Threshold
Divergent, Below Threshold
No Info
232
Convergent
Check Wheel Response
238
Below Threshold
Above Threshold
No Info
240
No Info
242
Increment Grounded Counter & Indicate "Possibly Grounded"
234
Counter Reaches Threshold
Identify Grounded Wheel
236
Small Input (~0)
Check Wheel State (Slip)
244
Large Slip
Small Slip
Check Response
246
Convergent
Non-Convergent
Increment Lifted Counter & Indicate "Possibly Lifted"
228
Counter Reaches Threshold
Identify Lifted Wheel
230
No Info
248

FIG.9

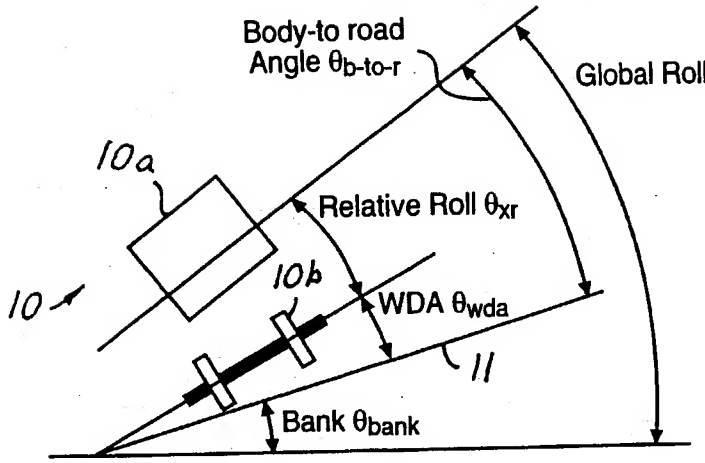
Body-to road
Angle $\theta_{b\text{-}to\text{-}r}$
Global Roll θ_x
10a
Relative Roll θ_{xr}
10
10b
WDA θ_{wda}
11
Bank θ_{bank}

FIG.10

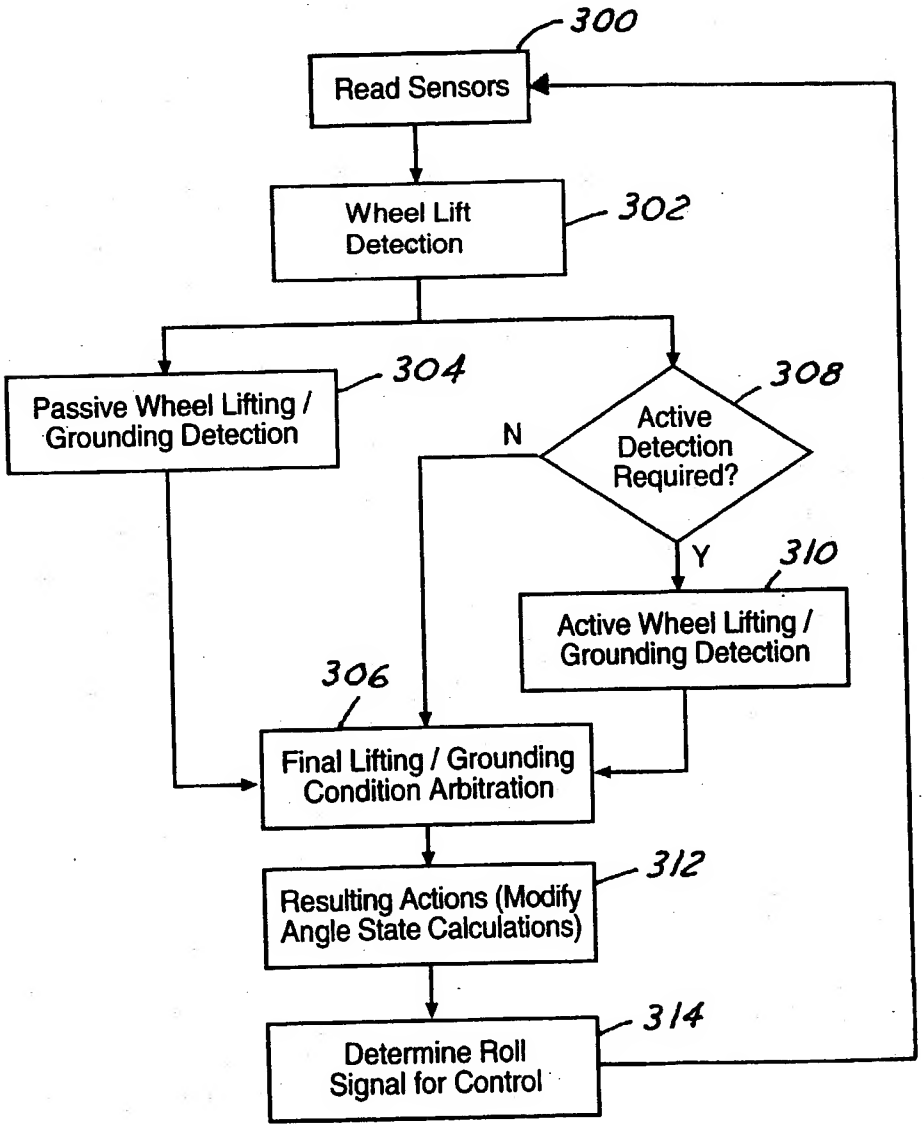
300
Read Sensors
Wheel Lift Detection
302
Passive Wheel Lifting / Grounding Detection
304
Active Detection Required?
308
N
Y
310
Active Wheel Lifting / Grounding Detection
306
Final Lifting / Grounding Condition Arbitration
Resulting Actions (Modify Angle State Calculations)
312
Determine Roll Signal for Control
314

FIG.12

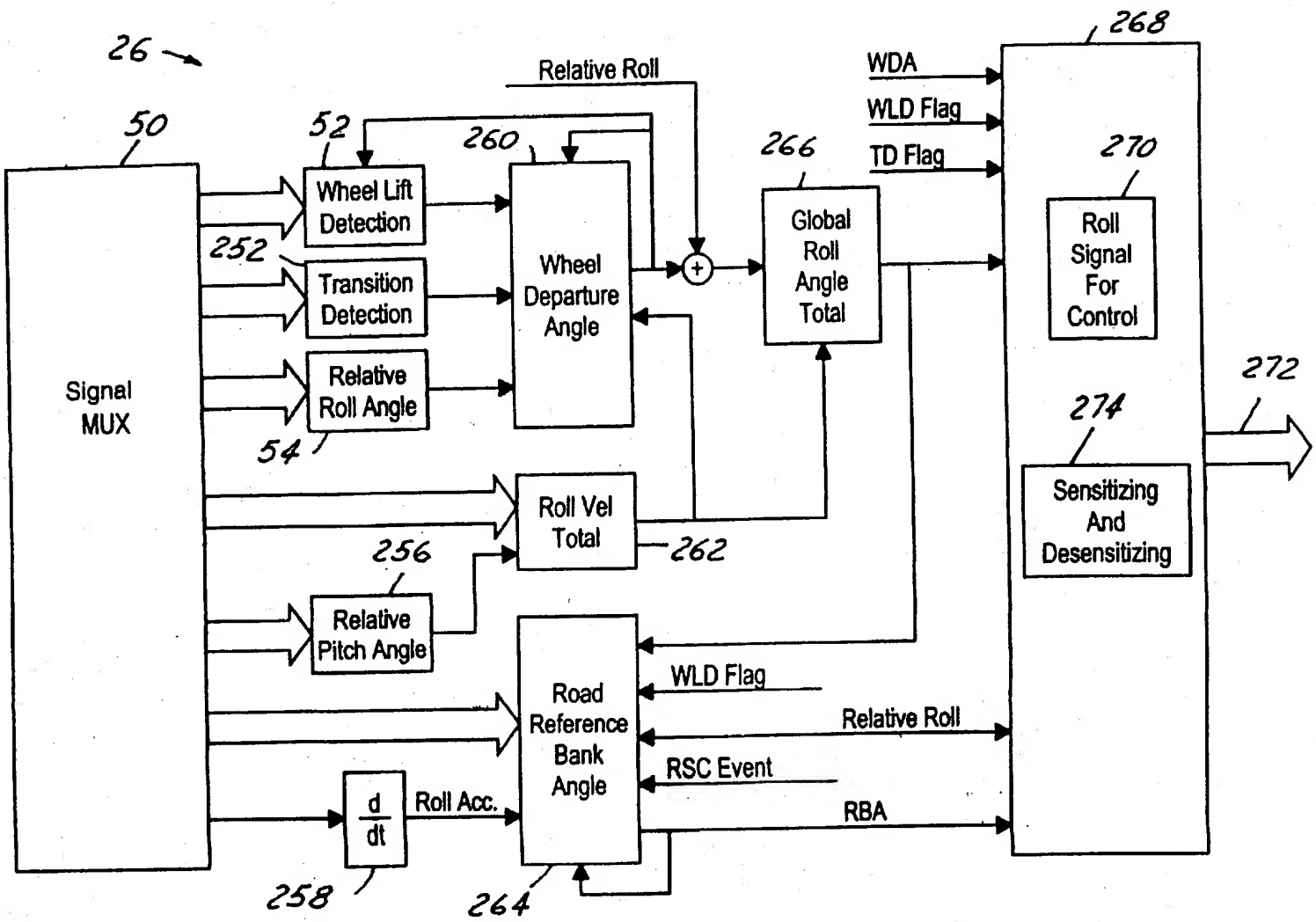
26
50
52
260
266
268
270
272
274
252
54
256
262
258
264
Signal MUX
Wheel Lift Detection
Transition Detection
Relative Roll Angle
Wheel Departure Angle
Relative Roll
Global Roll Angle Total
WDA
WLD Flag
TD Flag
Roll Signal For Control
Sensitizing And Desensitizing
Roll Vel Total
Relative Pitch Angle
Road Reference Bank Angle
WLD Flag
Relative Roll
RSC Event
RBA
d/dt
Roll Acc.

FIG. 11

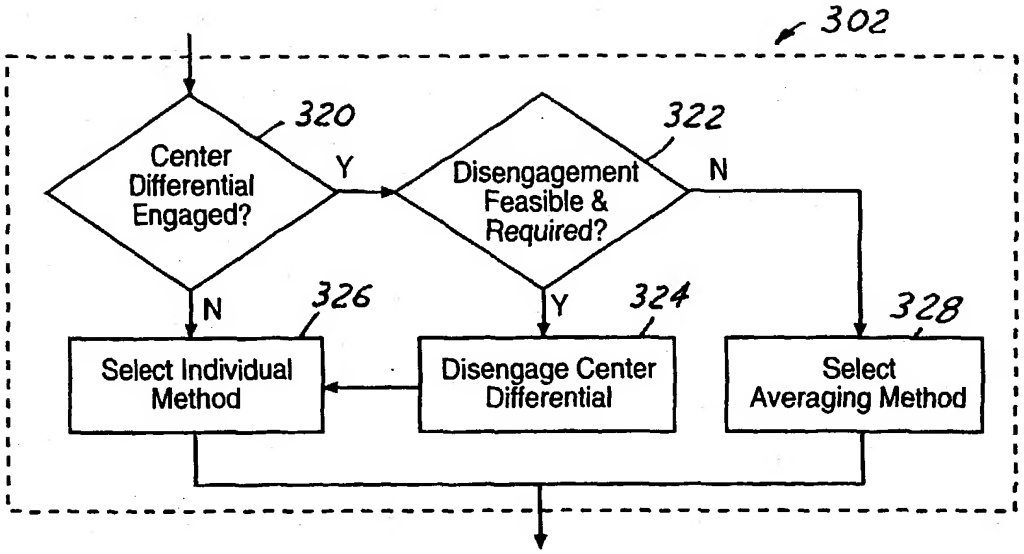
302
320
Center Differential Engaged?
Y
322
Disengagement Feasible & Required?
N
N
326
Y
324
328
Select Individual Method
Disengage Center Differential
Select Averaging Method

FIG.13

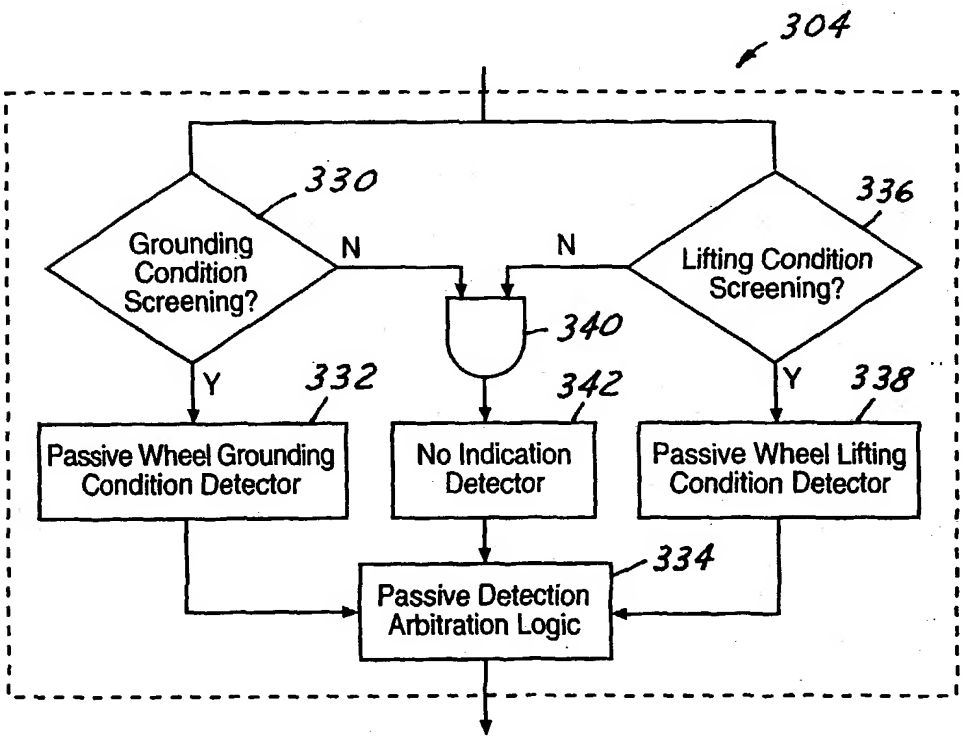
304
330
Grounding Condition Screening?
N
N
336
Lifting Condition Screening?
340
Y
332
342
Y
338
Passive Wheel Grounding Condition Detector
No Indication Detector
Passive Wheel Lifting Condition Detector
334
Passive Detection Arbitration Logic

FIG.14

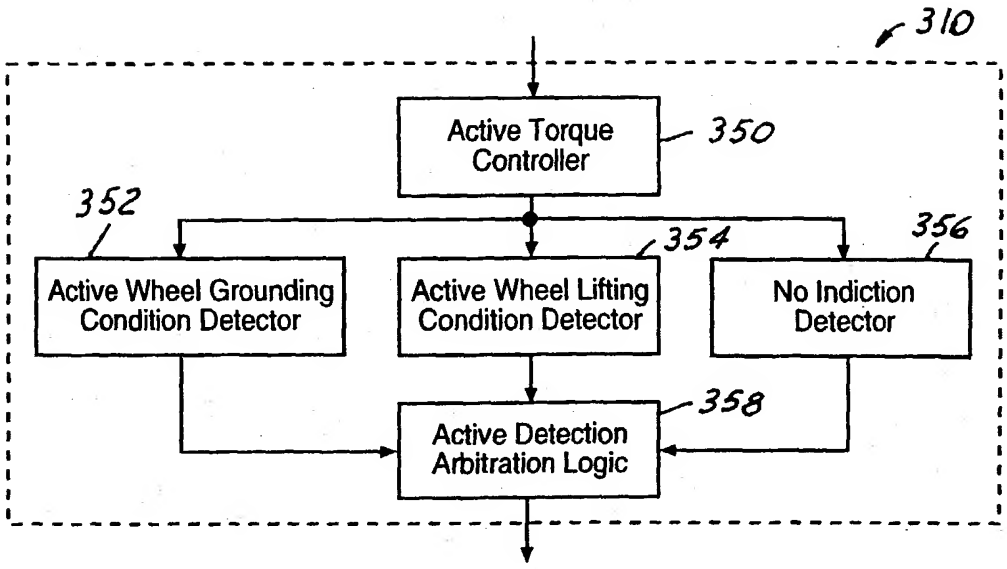
310
Active Torque Controller
350
352
354
356
Active Wheel Grounding Condition Detector
Active Wheel Lifting Condition Detector
No Indiction Detector
358
Active Detection Arbitration Logic

FIG.15

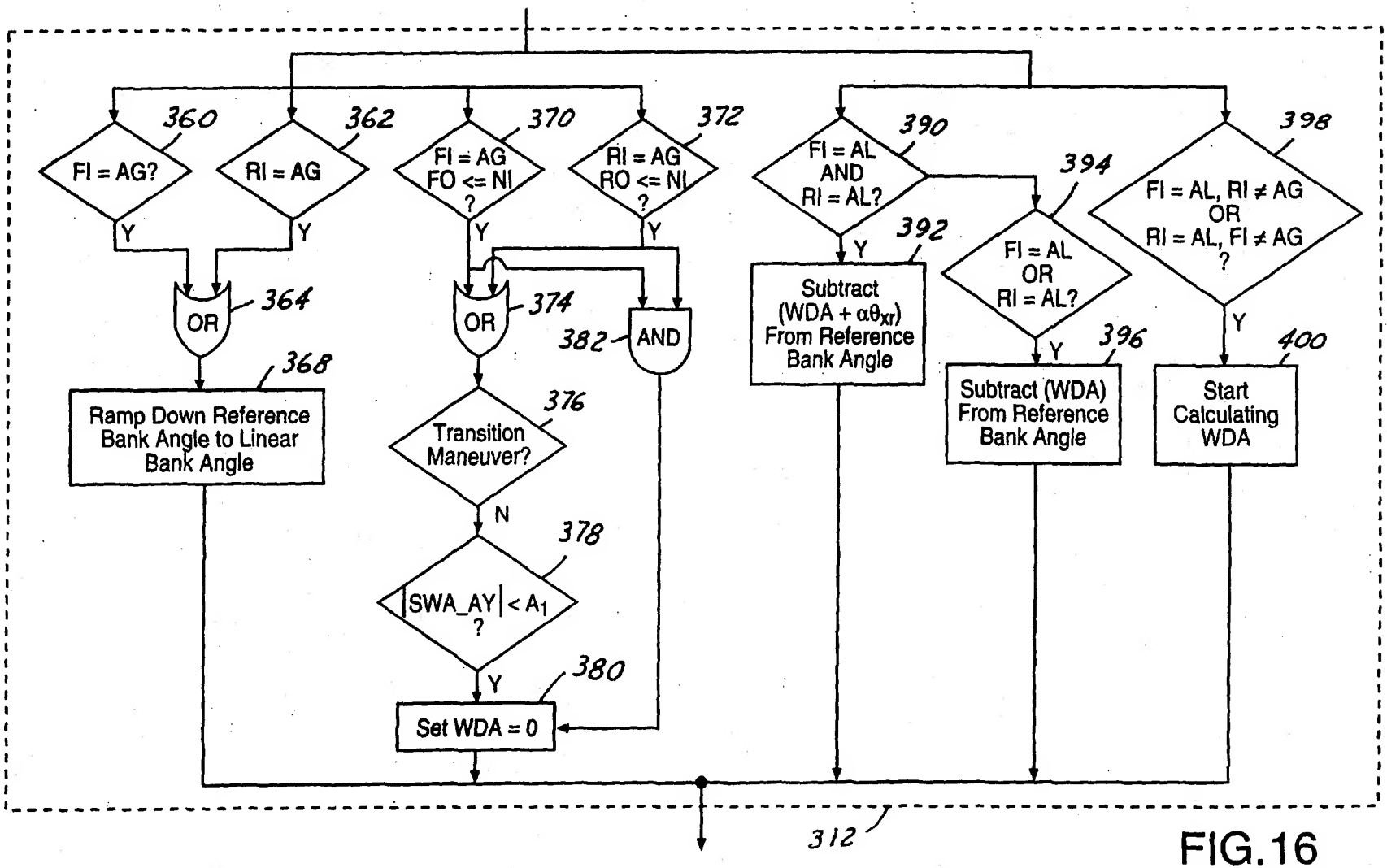
360
FI = AG?
Y
362
RI = AG
Y
370
FI = AG
FO <= NI
?
Y
372
RI = AG
RO <= NI
?
Y
390
FI = AL
AND
RI = AL?
Y
392
Subtract
(WDA + αθxr)
From Reference
Bank Angle
394
FI = AL
OR
RI = AL?
Y
396
Subtract (WDA)
From Reference
Bank Angle
398
FI = AL, RI ≠ AG
OR
RI = AL, FI ≠ AG
?
Y
400
Start
Calculating
WDA
OR
364
368
Ramp Down Reference
Bank Angle to Linear
Bank Angle
OR
374
382
AND
376
Transition
Maneuver?
N
378
|SWA_AY| < A1
?
Y
380
Set WDA = 0
312

FIG.16